International Journal of Electronics,
Communication & Instrumentation Engineering
Research and Development (IJECIERD)
ISSN(P): 2249-684X; ISSN(E): 2249-7951
Vol. 4, Issue 2, Apr 2014, 69-74

TRANS STELLAR
• Journal Publications • Research Consultancy

SPEED CONTROL OF 3-ph INDUCTION MOTOR WITH TWO STAGE IPFC USING 1-ph SUPPLY

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ABSTRACT

Today in industries, 3-ph IM are being used on very wide scale. So, its speed control according to the specific requirement is very important. Also many times, 3-ph IM are to be operated with easily available 1-ph supply. For this, proposed mechanism of speed control here is very efficient and reliable. At input terminal, high performance Two stage Interleaved power factor correction technique (IPFC) with boost topology operating with discontinuous current conduction is used. With this circuit, 3^{rd} order harmonics can be eliminated upto 99.99%. Also it will help to achieve almost UNITY pf with rated power supply. With this type of 3-ph supply provided to the IM, Reactive power generation can be minimised which leads to efficient control over the wastage of Reactive power and use the Reactive power compensation techniques. So the overall cost of operating 3-ph IM can be minimised.

KEYWORDS: Two Stage Boost Topology, Discontinuous Current Conduction, IPFC, Sine-Wave PWM, 3-ph Bridge Inverter

INTRODUCTION

Today in industries, the speed of induction motor can be effectively controlled by V/f method. By maintaining V/f ratio constant throughout the operation this controlling can be achieved. But problem still persist with power factor correction. Active PFC is said to be better method for this. But it is unable to improve input power factor to the desired level of efficiency. So another improved method for power factor correction and hence the output speed of 3-phase induction motor is stated here known as Interleaved Power Factor Correction (IPFC).

With this method, nearly Unity power factor can be achieved which helps in reducing the Third Order Harmonics. The 3^{rd} order harmonics are mainly responsible for reduction in the overall efficiency of the Induction Motor by introducing ripples in the input supply.

OBJECTIVE

As we know Converters are the best option for situations where three phase AC supply is not available, advanced Sine-PWM techniques are employed to achieve output voltage with minimum distortion. In this paper, we are introducing a new technique Two-stage IPFC (Interleaved power factor correction) to improve the quality of input voltage supply thereby improving quality of output voltage. Thus giving maximum efficiency of the 3-phase Induction Motor. The proposed IPFC technique for effective controlling of motor used here gives input voltage with almost 99% reduced harmonics. With this method, as the input voltage is optimised at supply side only therefore the use of filter circuit will be eliminated which will reduce overall cost of operation and speed control of the 3-phase IM. The function of filter stage and PFC (Power Factor Correction) stage will be performed by IPFC stage alone. Therefore the space required for the

mounting of the circuit will be less. Therefore this method will be more efficient than all the existing methods.

INTERLEAVED POWER FACTOR CORRECTION

Interleaved Power Factor Correction (IPFC) stage improves the input power factor by reducing significance of mainly 3rd order harmonics. Without such a PFC stage, the current drawn will have significant harmonic contents. This, in turn, will result in increased network losses, radiated emission and total harmonic distortion. At higher power levels, these problems become more pronounced, thereby reducing overall efficiency of the system.

The aim of IPFC is to provide resistive input impedance, means the input power factor must be UNITY. This allows maximum use of active power thus reducing the generation and hence use of reactive power. Therefore the problem of reactive power compensation is also eliminated.

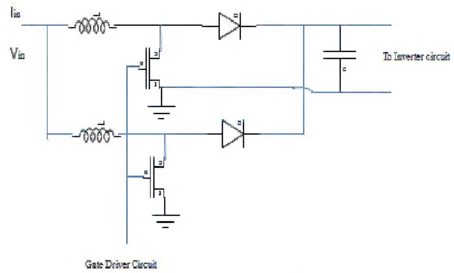

Figure 1: Interleaved Power Factor Correction

In the first stage, DC input supply to the above circuit is fed from output of bridge rectifier circuit. This supply is then distributed in parallel branches. If this distribution can be set to 50% in each branch, approximately UNITY power factor can be achieved.

This type of distribution can be achieved by selecting proper magnitude of Inductance of the boost converter. The output from this stage will then be added together to get ripple free supply. This will eliminate the need for filter circuit to be used. Thus the output of two stage interleaved power factor correction circuit will be at approximately UNITY power factor. This output voltage from IPFC circuit will then fed to 3-phase IM via 3-phase bridge inverter circuit. This improved input supply will improve the speed controlling and hence its efficiency up to 98%. With the existing control techniques this efficiency will never go beyond 95%.

With such PFC, the reactive power generation will be negligible as input power factor will be improved to approximately UNITY. This will also minimize the cost of reactive power compensation circuitry. Thus the overall cost for speed control reduces and efficiency of the 3-phase induction motor used will increase because of the reduction in harmonics by achieving UNITY power factor.

INTERLEAVED BOOST TOPOLOGY

In the IPFC technique explained above, two boost circuit are arranged in parallel connection. The two inductors in parallel will share total load equally. And by providing proper switching signals to MOSFET, the desired magnitude of supply will be provided to the inverter section.

The working of interleaved boost topology can be explained as below:

The interleaved boost topology can be arranged as two boost converter circuit connected in parallel operating

180° out of phase in discontinuous mode of operation. The input current is the sum of the two inductor branch currents IL1 and IL2. Because the inductor's ripple currents are 180°out of phase, they will cancel out each other and reduces the input ripple current caused by the inductors.

The best input inductor ripple current cancellation can be achieved at 50 percent duty cycle, which means input supply must be shared by both inductors equally. The current across output capacitor will be, ICout = (I1 + I2 -Iout). Where Iout is the output current. Interleaving reduces the output capacitor ripple current (IOUT) as a function of duty cycle.

PULSE WIDTH MODULATION

The efficient method of controlling the output voltage is to incorporate PWM techniques within the inverter. This technique also helps in reducing the harmonics if remained after IPFC stage in the output voltage. Commonly used PWM techniques are

- Single pulse modulation.
- Multiple pulse modulations.
- Sinusoidal pulse modulation

Sinusoidal PWM is most used and trusted method in industries. One of the major issues with PWM is the presence of harmonics. The higher order harmonics around the carrier frequency are relatively easier to filter out, but the lower order harmonics smaller in magnitude and cause problems for the PWM inverters. To reduce these lower order harmonics a variety of techniques have been proposed. Sinusoidal pulse width modulation (SPWM) technique is used to generate gate pulses. SPWM is a very simple technique for harmonic reduction. In this technique pulse magnitude will be constant and only pulse width can be changed. In this pure sine wave is compared with triangular wave for producing gate pulses.

V/f CONTROL METHODOLOGY

Induction motor control is complex due to its nonlinear characteristics. While there are different methods for control, Variable Voltage Variable Frequency (VVVF) or V/f is the most common method of speed control in open loop. This method is most suitable for applications without position control requirements or the need for high accuracy of speed control. The frequency and speed of the motor, with respect to the input supply, is called the synchronous frequency and synchronous speed. Synchronous speed is directly proportional to the ratio of supply frequency and number of poles in the motor. Synchronous speed of an induction motor is shown in Eqn.

Synchronous Speed (Ns) = (120 x f)/P

Synchronous speed is the speed at which the stator flux rotates. Rotor flux rotates slower than synchronous speed by the slip speed. This speed is called the base speed. The speed listed on the motor nameplate is the base speed.

Base Speed N = Synchronous Speed – Slip Speed

Percent Slip = [(Synchronous Speed – Base Speed) x 100]/ Synchronous Speed.

Stator Voltage (V) ∝ [Stator Flux (φ)] x [Angular Velocity (ω)]

$V \propto \varphi \times 2\pi f$

$\varphi \propto V/f$

By maintaining V/f ratio constant throughout the operation of motor, efficient control of motor can be achieved. One can vary either voltage or frequency of the supply in order to control the speed of induction motor to be used.

WORKING

The circuit diagram of the operation is given below:

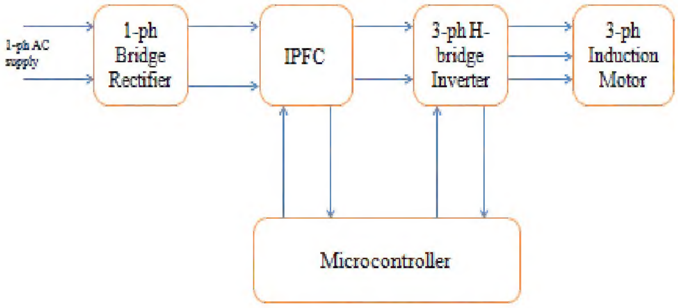

Figure 2: Working Diagram

The circuit is schematic of implemented speed control of three phase induction motor using single phase supply along with interleaved power factor improvement is as shown in Figure The circuit diagram can be divided into three parts. Part 1 consists of diode bridge rectifier. This circuit will convert the 1-phase AC supply into DC output with some distortions. This output can be termed as sinusoidal DC output. It will then be fed to the two stage interleaved power factor correction circuit which is the second part of this circuit. In this circuit, the input power supply is divided equally among two boost branches. With the MOSFET operating at 50% duty cycle, the ripple occurring due to inductor current can be eliminated completely. So that pure DC supply can be given to the inverter circuit to be fed it to the 3-phase induction motor which is to be operated as load. The boost switch is turned ON at constant frequency with constant ON time. This is done with discontinuous mode of conduction. Since this switching frequency is usually very high (kHz), filtering of the unwanted input current harmonics becomes a relatively easy task and can be achieved with the help of a small input capacitor and inductor. Therefore the overall input power factor after filtering (i.e. at ac source) is very close to unity.

Part 3 represents three phase voltage source sine PWM inverter. POWER MOSFETS are being used as switching devices along with anti-parallel diodes. The boosted dc voltage is connected to three phase induction motor through a three phase bridge inverter with a suitable control circuitry which changes the switching frequency of inverter from 20 to 25kHz which leads to the control of the frequency and the output of inverter from 0 to 50Hz. For Continuously variable speed control, the output frequency of inverter must be varied. The applied voltage to the motor must also be varied in linear proportion to the supply frequency to maintain constant motor flux. At low frequency, where the motor inductive reactance is low, boosted voltage is used to compensate for the stator IR voltage drop. Thus control of both voltage and frequency is necessary for proper variable speed operation.

CONCLUSIONS

This IPFC converter for effective speed control of motor is most suitable for rural areas where 3-phase pump motors are to be operated with easily available 1-phase supply with reduced harmonics distortion and compensation of

reactive power is also achieved. IPFC also improves input current with discontinuous conduction current. With the use of IPFC overall efficiency of the system can be improved by significant amount.

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